Deliverable 2 – Final Report and Proposed P Soil Test Calibration
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Developing a Calibrated P Fertilizer Recommendation for EAA Sugarcane for Organic Soils: Assessment of Soil-P Extraction Methods and their Correlation to Sugarcane Yields under Variable Inputs

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Introduction

A calibrated soil test for phosphorus (P) is an important best management practice for sugarcane growers in the Everglades Agricultural Area (EAA). Approximately 400,000 acres in the EAA are in sugarcane production. Soil test calibration requires field research that correlates soil test P levels to observed crop yield responses to varied rates of P fertilizer.

The University of Florida/IFAS Everglades Soil Testing Laboratory (ESTL) provides a calibrated soil test for sugarcane. This calibration is based on a water extraction (P_w) that was originally developed for vegetable crops in the mid-1940's. The P_w is designed to estimate readily soluble P fractions, appropriate for short-season low-biomass vegetable crops, but inadequate for estimating long-term P supply to multi-year high-biomass sugarcane crops. The ESTL also routinely determines acetic acid-extractable soil P (P_a), which provides an estimate of more strongly bound soil P that becomes available over a period of time. Previous research indicated that the acetic acid test might be an improvement over the water test. The Bray 2 and Mehlich 3 soil extractants were also included in the study as potential replacements for the water extractant. The Bray 2 extractant is currently used on organic soils and has a published P calibration for sugarcane (Andreis and McCray, 1998). Mehlich 3 is widely used as an extractant on many different soil types.

This study has the objective of evaluating several potential soil test extractants to determine the best relationship between soil test P and sugarcane production response to fertilizer P on organic soils in Florida. This final report presents crop response to fertilizer P, soil and leaf P concentrations, and a proposed new soil test P calibration.

Materials and Methods

Comparisons of sugarcane production response to P fertilizer were made in four field locations (designated P7, P8, P9, and P10) on organic soils in south Florida. Initial pH and extractable soil P values are shown in Table 1. Annual banded P fertilizer rates at each test location were 0, 19, 37, 75, 150, and 300 lb P_2O_5/acre. At two test locations (P7 and P8) banded P rates were also compared with broadcast applications. Small plots at each location were each 30 ft (6 rows) X 43.5 ft (0.03 acres). Randomized complete block designs were used at each location with 6 replications at the P7 and P10 locations, 7 replications at P8, and 5 replications at P9.

Leaf samples were taken in the June-July period each year for each test. Top visible dewlap leaves were sampled from the 4 middle rows of each plot (32 leaves/plot), the midrib was stripped out of each leaf, and leaf blades were rinsed in deionized water. Each leaf sample was then placed in a paper bag and dried at 60º C. Dried leaf samples were ground in a Wiley mill to pass a 1 mm screen. Leaf samples were analyzed for N, P, K, Ca, Mg, Fe, Mn, Zn, and Cu concentrations.

Soil samples were taken after harvest each year. Samples were taken in the row to 0-6 and 6-12 inch depths. Samples were screened and air-dried to prepare them for analysis. Soil-water pH was determined for all samples. Volumetric soil extractions to determine soil P concentrations were done with 5 methods. Acetic acid-extractable P (P_a) was determined with 0.5 N acetic acid using a 4 cm^3 soil/50 cm^3 extractant ratio. Soil samples were allowed to stand in the extractant overnight and then were shaken for 50 minutes before filtering for P analysis. Modified acetic acid-extractable P was determined with the same extractant but using a 10 cm^3 soil/25 cm^3 extractant ratio. Soil samples were allowed to stand in the extractant overnight and then were shaken for 50 minutes before filtering for P analysis. Water-extractable P was determined with deionized water using a 4 cm^3 soil/50 cm^3 extractant ratio. Soil samples were allowed to stand in the extractant overnight and then were shaken for 50 minutes before filtering for P analysis. The Bray 2 extractant (0.03 N NH_4F and 0.1 N HCl) was used in a 2.5 cm^3 soil/16 cm^3 extractant ratio. Soil samples were allowed to stand in the extractant for 10 minutes and then shaken for 5 minutes before filtering for P analysis. The Mehlich 3 extractant (0.2 N CH_3COOH, 0.25 N NH_4NO_3, 0.015 N NH_4F, 0.013 N HNO_3, and 0.001 M EDTA) was used in a 2.5 cm^3 soil/25 cm^3 extractant ratio with a 5 minute shaking time immediately after adding the extractant to soil samples. Phosphorus concentrations were determined with a probe colorimeter using the phosphomolybdate blue method (Murphy and Riley, 1962).

Sugarcane harvest data were collected each year from each plot of each test location. Counts of harvestable stalks were made in the 4 middle rows of each plot in the period of August-September each year. Weights of 40-stalk samples from the 4 middle rows of each plot were determined during the period of October-January each season with samples being collected as near the time of commercial harvest for a field as possible. Stalk counts and stalk weights were used to estimate tons cane/acre. Ten stalks were randomly selected from each 40-stalk sample and crushed for juice analysis for determination of sucrose concentration and estimation of tons sugar/acre.

Statistical analysis was performed using the Statistical Analysis System (SAS, 2003). Analysis of variance was done using the GLM procedure and means were compared using least significant difference (LSD) and contrast procedures. Sigmaplot (Systat, 2006) was used for plotting graphical data.

Results and Discussion

Crop Yield Responses

Table 1 shows initial soil test values for the four test sites. These values are presented to indicate soil test P values before any P fertilizer was applied in the test. Tables 2-5 show harvest data comparisons for the three years of the test at the P7 site. In the first year of the test at P7 there was a small difference in tons cane/acre (TCA) between P rates, but no significant difference in tons sugar/acre (TSA). There were more significant differences in TCA and TSA between P rates in the first and second ratoon crops (Tables 3 and 4). With the second ratoon crop at P7 there was a significant interaction between fertilizer P rate and placement of P fertilizer (band versus broadcast). There was a similar crop response to a banded application of 37 lb P_2O_5/acre as to a broadcast application of 75 lb P_2O_5/acre (Table 5). This shows the importance of banding P fertilizer as a best management practice and highlights the need for new soil test criteria to be based on banded P fertilizer rates.

There were no significant differences in TCA, TSA, or percent sugar yield between P fertilizer rates at the P8 location (Table 6). This was a location that potentially could have shown differences between P rates based on initial soil test values (Table 1). However, there were problems with lack of stand and high weed population which overwhelmed a potential response to P fertilizer and so this test location was abandoned after the plant cane crop.

There was a strong response to P fertilizer at the P9 site which was established in the first ratoon crop (Table 7). There was a large increase in TCA and TSA with all P rates in each year of the test, with no crop response to P rates higher than 19 lb P_2O_5/acre. The initial P_a soil test was much higher than the P7 and P8 locations, but P_w was relatively low (Table 1).

There was not a significant crop response to P fertilizer at the P10 location (Table 8). There were effectively three control plots in each replication of this test because we had planned to use two of them to add P fertilizer only in the next ratoon crop. It was decided not to continue the test at this location because of variations in stand throughout the test. Initial soil test values were extremely high at this location and indicate that a response to P fertilizer would not be expected.

Extractable Soil P

Comparisons of extractable soil P among treatments for each test location are shown in Tables 9-14. Extractable soil P increased with increasing fertilizer P rate for all extractants in each sample year at the P7 site (Tables 9-10). There were also significant differences in extractable P between the band and broadcast treatments for all extractants at that location. The significant rate X placement interactions indicate that the amount of

P fertilizer applied affected the difference in extractable soil P between the band and broadcast treatments, with greater differences in the plant row between band and broadcast treatments at higher P rates.

At the P8 test site, soil extractable P also increased significantly with increasing P rate for all extractants (Table 11). Differences in extractable soil P between band and broadcast P were not as clear for all extractants at P8 as at P7, but extractable P trended higher in the row for banded P compared to broadcast P.

Only banded P fertilizer rates were applied in the P9 and P10 tests. In the P9 test, extractable soil P increased significantly with increasing P rate for all extractants (Tables 12-13). Variations in the amount of P extracted by the different extractants at each location are evident. Control plot acetic acid-extractable P/water-extractable P ratios for P7, P8, and P9 were 20.5, 14.9, and 33.7, respectively in the first year of each test (Tables 9, 11, and 12). In this location the current soil test calibration using water would have recommended 40 lb P_2O_5/acre for a first ratoon crop based on a water-extractable P value of 4 lb P/acre (converting 2.6 mg P/dm^3 to lb/acre using a conversion factor of 1.36; Appendix A). Using a proposed calibration with acetic acid by Korndorfer et al. (1995), no P would have been recommended at this site.

Extractable soil P values at the P10 site were extremely high for all extractants (Table 14). Only water-extractable P increased significantly with increasing P rate. There was a lot of variability at this site in terms of crop stand and soil test values, but no response to fertilizer P was found at this site as would be expected.

Leaf P Concentrations

Leaf P concentration was significantly affected by P fertilizer rate each year of the P7 test (Table 15). Control plot leaf P concentration was below the critical value of 0.19% in the first and second ratoon crops (2006 and 2007) (Anderson and Bowen, 1990). Some other treatment means were below the optimum range of 0.22-0.30% in 2006 and 2007. Overall leaf P concentrations were somewhat lower in 2006, but adequate P supply should not have been a problem at the higher P rates. In 2007 there was a higher leaf P concentration with the banded P application compared to the broadcast application, which supports the use of banded fertilizer P which concentrates applied fertilizer in a localized area in the root zone.

Leaf P concentration was not significantly affected by fertilizer P rates at the P8 site (Table 16). Leaf P concentration mean for the control plots was within the optimum range (0.22-0.30%), but was low enough that there could potentially have been a response to fertilizer P in ratoon crops if the test had not been discontinued because of stand and weed problems.

At the P9 site, leaf P concentration was significantly increased with increasing P fertilizer rate in each year of the test (Table 17; first and second ratoon crops). Control plot mean leaf P concentration was below the critical value (0.19%) each year, with the value in 2007 (0.12%) being extremely low. Sugarcane in plots with no fertilizer P was stunted with much lower production and so leaf P concentration was a good indication of extreme P deficiency at this location.

There were no significant differences in leaf P concentration among P fertilizer rates at the P10 site (Table 18). All mean leaf P concentrations were well above the lower end of the optimum range (0.22%). High leaf P concentration is expected at this location given the extremely high levels of extractable soil P (Table 14).

Relationships Between Soil P and Tons Sugar/Acre

In order to develop a calibrated soil test it is important to examine how extractable soil P relates to crop production at multiple locations of the soil type under consideration. In terms of sugarcane, tons sugar/acre (TSA) is the best measure since sugar is the product being marketed and since TSA incorporates biomass (tons cane/acre) and sucrose (% sugar yield) factors. Relative crop yield is often used to develop soil test calibrations since it takes into consideration differences in growth potential and other factors between locations. Initial soil test value before establishment of a fertilizer rate test is a useful measure to relate with relative crop yield in the case of Florida sugarcane because with band applications of fertilizer, obtaining representative soil test values annually for the subsequent ratoon crops is difficult (Gascho and Kidder, 1979). Figure 1 shows the relationship between relative sugar/acre and initial acetic acid-extractable soil P in previous published and unpublished P rate studies and includes data from Korndorfer et al. (1995) and Glaz et al. (2000). Relative sugar/acre values are calculated by dividing the mean tons sugar/acre of control plots (no P fertilizer) by the highest mean tons sugar/acre of any P fertilizer treatment. Each point in Figure 1 represents the relative yield of plots receiving no P fertilizer in that crop year compared with plots receiving adequate P. Figure 1 shows a strong relationship between relative sugar yield and acetic acid-extractable soil P.

Figures 2-6 show relationships between relative tons sugar/ha and extractable soil P using each of the 5 extractants used in our study. Initial soil test values used in these figures include values from Tables 1 and include the P7, P8, and P9 locations. The P10 location is not included in these graphs because extractable soil P was extremely high there and because there was no response to added P fertilizer. Also included in Figures 2-6 are initial soil test values shown in Table 19 which are from previous UF/IFAS tests P4, P5, and P6 conducted by Dr. Ron Rice and Dr. Yigang Luo, and data from unpublished tests conducted by Dr. Mabry McCray previously at the United States Sugar Corporation. These specific experiments were used for Figures 2-6 because all 5 extractants could be compared in most of these locations.

The relationship between relative tons sugar/acre and initial acetic acid-extractable soil P in Figure 2 is very similar to the relationship in Figure 1, except for 3 points in Figure 2 (indicated by arrows) with relatively high extractable P, but which showed strong responses to fertilizer P. One of these points is the last year of the P5 test and the other 2 points are the 2 years of the P9 test. These 2 tests are in the same field and so evidently the acetic acid extractant is removing more P from the soil at that location than is actually available to the crop. The response to P fertilizer at the P9 site was very strong (Table 7) and also supported by extremely low leaf P concentrations in control plots (Table 17). It is very important that a new soil test P calibration account for the fertilizer response at this location. Acetic acid as a stand-alone soil extractant for P does not appear to be a good choice.

The relationship between relative tons sugar/acre and initial modified acetic acid-extractable soil P (Figure 3) is similar to that in Figure 2, except that modified acetic data was not available for the 2 U. S. Sugar tests and so reduced yield at low extractable P values is missing from the graph. Similar to Figure 2, however, are the 3 points with reduced yield at relatively high extractable values. These 3 points represent the same years of the P5 and P9 tests that showed a problem with the regular acetic acid test. The modified acetic acid test uses the same extractant as the regular acetic acid test but the extractant/soil ratio is narrower and so less P is extracted from the soil. Modified acetic acid would also not be a good choice for a new calibration.

Figure 4 shows the relationship between relative tons sugar/acre and water-extractable P. The 4 points indicated with arrows are all from the USSC2 test. This location had a soil pH of 4.8, which is relatively acid but is within the range found in organic soils in Florida. The water extractant is currently used as the calibrated soil test for sugarcane grown on organic soils in Florida. The relatively high amount of P extracted at the USSC2 site illustrates the problem that the water extractant has with being highly pH-dependent. Water extracts more P in acid soils compared with soils of higher pH and Figure 4 shows that the amount of P extracted in acid soils does not relate well to crop P availability. The USSC2 test actually showed a very strong response to P fertilizer. This illustrates the need to replace the water extractant with a new soil test calibration.

The relationship between Bray 2-extractable soil P and relative tons sugar/acre appears to have potential with the exception of the 2 points indicated by arrows. These 2 points are from the P9 test in which a relatively high amount of P was extracted by the Bray 2 extractant in spite of a strong response to P fertilizer at that location. This problem is similar to that found with acetic acid in which more P is extracted for the soil at a particular location than is actually available to the crop.

There was a strong relationship between Mehlich 3-extractable soil P and relative tons sugar/acre (Figure 6). The primary crop response to fertilizer P was found at Mehlich 3 P values less than 15 mg/dm^3. The highest Mehlich 3 soil P value with a significant crop response was at the P4 location (Tables 19-20) in previous work by Ron Rice and Yigang Luo in the plant cane crop with an initial Mehlich 3 value of 28.7 mg P/dm^3. Differences in crop year account for some of the variation in relative tons sugar/acre at Mehlich 3 soil values less than 15 mg P/dm^3. There was greater crop response to P fertilizer in ratoon crops in general than in plant cane crops. The nonlinear regression line shown in Figure 6 indicates that 80%, 90%, 95%, and 98% relative tons sugar/acre might be expected with no added fertilizer P with initial Mehlich 3 soil P values of 9, 13, 19, and 29 mg/dm^3, respectively. Substantially greater production losses than that can be found especially in ratoon crops as indicated by points below the regression curve at Mehlich 3 values $\leq$ 15 mg P/dm^3.

Proposed Soil Test Calibration

A new sugarcane P fertilizer calibration is proposed in Table 21. The highest P fertilizer rate is 75 lb P_2O_5/acre, which is the highest current recommendation (Appendix A) and is the highest P rate to which a significant response of tons sugar/acre was found in tests by IFAS or the United States Sugar Corporation (Andreis and McCray, 1998; McCray, unpublished data). This 75 lb P_2O_5/acre rate is assigned to the soil test range where a response to this rate has been found, $\leq$ 10 mg P/dm^3. The zero rate of fertilizer P for plant cane was set slightly above the highest soil test level at which a response was observed (28.7 mg P/dm^3; P4 site), so that at Mehlich 3 values > 30 mg P/dm^3 no P would be recommended for plant cane. Intermediate categories were established between soil test values of 10 and 30.

It has been observed that soil test P levels can decrease substantially during the course of several years (Table 22). Since there is a problem with collecting representative soil samples annually for ratoon crops with banded P fertilizer in sugarcane, it is recommended to base ratoon crop P fertilizer on the initial soil sample taken before the cane crop is planted (Gascho and Kidder, 1979). This makes it important to allow for decrease in soil test P over time in making recommendations for ratoon crops. For that reason the ratoon crop 1 and 2 rate of 40 lb P_2O_5/acre is extended up to an initial Mehlich 3 soil test value of 35 mg P/dm^3. For ratoon crops 3 and beyond, this upper soil test value is extended to 40 mg P/dm^3.

The Mehlich 3 extractant was successful at predicting crop response to added P fertilizer across a range of soil characteristics at different locations on organic soils in south Florida. This extractant is the best choice as a replacement for the current water extractant and will greatly improve our ability to make appropriate P fertilizer recommendations for sugarcane.

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Table 1. Initial soil test values at the four phosphorus fertilizer rate tests.

Location	pH	Acetic	Mod Acetic	Water	Bray 2	Mehlich 3
		------------------------	mg P/dm^3	------------------------		
P7	6.2	26.6	3.8	1.3	15.5	10.3
P8	6.2	25.3	4.2	1.7	23.7	19.2
P9	6.9	87.7	21.6	2.6	20.3	11.5
P10	7.0	605.1	313.3	35.4	395.5	344.6

Extractable mg P/dm^3 is equivalent to mg P/L soil.

Table 2. Sugarcane harvest data for the plant cane crop of the P7 phosphorus fertilizer rate test.

	tons cane/acre	**tons sugar/acre**	**% sugar yield**
No P	59.3	6.99	11.76
Contrast 0 vs Others	NS	NS	NS
lb P_2O_5/acre	*	NS	NS
19	57.5	6.64	11.50
37	59.8	6.95	11.58
75	60.6	7.02	11.60
150	64.0	7.33	11.42
300	63.3	7.29	11.49
LSD (0.05)	4.3	0.57	0.33
Placement	NS	NS	NS
Band	60.9	7.03	11.51
Broadcast	61.2	7.07	11.52
LSD (0.05)	2.7	0.36	0.21
Rate X Placement	NS	NS	NS

* Differences between treatments are significant at the 95% confidence level.
NS Differences between treatments are not significant at the 90% confidence level.

Table 3. Sugarcane harvest data for the first ratoon crop of the P7 phosphorus fertilizer rate test.

	tons cane/acre	tons sugar/acre	% sugar yield
No P	47.5	6.33	13.36
Contrast 0 vs Others	NS	NS	NS
lb P_2O_5/acre	*	*	NS
19	45.0	6.17	13.72
37	49.2	6.72	13.67
75	50.5	6.78	13.42
150	50.1	6.78	13.56
300	51.3	6.96	13.56
LSD (0.05)	3.9	0.53	0.30
Placement	NS	NS	NS
Band	48.8	6.64	13.63
Broadcast	49.6	6.71	13.55
LSD (0.05)	2.5	0.34	0.19
Rate X Placement	NS	NS	NS

* Differences between treatments are significant at the 95% confidence level.
NS Differences between treatments are not significant at the 90% confidence level.

Table 4. Sugarcane harvest data for the second ratoon crop of the P7 phosphorus fertilizer rate test.

	tons cane/acre	tons sugar/acre	% sugar yield
No P	38.1	5.28	13.9
Contrast 0 vs Others	*	*	NS
lb P_2O_5/acre	†	†	NS
19	40.5	5.58	13.79
37	40.8	5.71	13.99
75	43.5	6.03	13.86
150	44.1	6.20	14.07
300	43.6	6.04	13.85
LSD (0.05)	3.1	----	----
Placement	NS	NS	NS
Band	43.2	6.03	13.94
Broadcast	41.8	5.80	13.89
LSD (0.05)	2.0	0.29	0.16
Rate X Placement	†	†	NS

*, † Differences between treatments are significant at the 95 or 90% confidence level, respectively.
NS Differences between treatments are not significant at the 90% confidence level.
LSD values could not be calculated for rate comparisons of tons sugar/acre or percent sugar yield because of missing values.

Table 5. Sugarcane harvest data for fertilizer rate and placement combinations in the second ratoon crop of the P7 phosphorus fertilizer rate test.

lb P_2O_5/acre	Placement	tons cane/acre	tons sugar/acre
0	None	38.1	5.28
19	Band	41.9	5.84
37	Band	44.0	6.12
75	Band	43.4	6.06
150	Band	42.9	6.04
300	Band	43.6	6.05
19	Broadcast	39.0	5.36
37	Broadcast	37.7	5.29
75	Broadcast	43.6	5.99
150	Broadcast	45.2	6.36
300	Broadcast	43.7	6.03
LSD (0.05)		4.5	----

LSD values could not be calculated for rate comparisons of tons sugar/acre because of missing values.

Table 6. Sugarcane harvest data for the plant cane crop of the P8 phosphorus fertilizer rate test.

	tons cane/acre	tons sugar/acre	% sugar yield
No P	41.5	5.06	12.15
Contrast 0 vs Others	NS	NS	NS
lb P_2O_5/acre	NS	NS	NS
19	36.8	4.40	11.94
37	38.1	4.54	11.91
75	39.6	4.82	12.13
150	35.5	4.25	11.80
300	37.6	4.53	11.97
LSD (0.05)	5.9	0.71	0.35
Placement	NS	NS	NS
Band	37	4.43	11.91
Broadcast	38.1	4.59	11.99
LSD (0.05)	3.7	0.45	0.22
Rate X Placement	NS	NS	NS

NS Differences between treatments are not significant at the 90% confidence level.

Table 7. Sugarcane harvest data for the first and second ratoon crops of the P9 phosphorus fertilizer rate test.

lb P_2O_5/acre		tons cane/acre		% sugar yield		tons sugar/acre		Cumulative
2007/08	2008/09	2007/08	2008/09	2007/08	2008/09	2007/08	2008/09	sugar/acre
0	0	39.2	18.4	13.92	12.70	5.46	2.33	7.78
19	19	54.1	44.0	13.66	12.93	7.40	5.69	13.09
37	37	52.0	42.6	13.39	12.52	6.97	5.33	12.31
75	75	53.7	46.7	13.60	12.65	7.32	5.90	13.23
150	150	57.8	47.7	13.53	12.10	7.83	5.77	13.60
300	300	57.6	45.0	13.30	12.63	7.67	5.69	13.36
0	37	43.3	45.9	13.92	12.62	6.00	5.79	11.79
0	75	40.7	48.2	13.95	12.55	5.68	6.03	11.70
	F-test	***	***	**	***	***	***	***
	LSD (0.05)	6.9	10.1	0.34	0.29	0.92	1.28	1.94

, * Differences between treatments are significant at the 99 or 99.9% confidence level, respectively.

Table 8. Sugarcane harvest data for the second ratoon crop of the P10 phosphorus fertilizer rate test.

lb P_2O_5/acre	**tons cane/acre**	**tons sugar/acre**	**% sugar yield**
0 (Control 1)	56.1	6.56	11.70
0 (Control 2)	58.5	6.71	11.48
0 (Control 3)	59.8	7.07	11.84
19	61.2	6.90	11.30
37	54.6	6.36	11.63
75	56.6	6.67	11.72
150	60.6	6.82	11.30
300	61.9	7.67	12.39
F-test	NS	NS	NS
LSD (0.05)	6.6	0.98	0.94

NS Differences between treatments are not significant at the 90% confidence level.

Table 9. Soil-extractable P in the P7 test in 2006.[1]

	Acetic	Mod Acetic	Water	Bray 2	Mehlich 3
	--------------------------mg P/dm^3-------------------				
No P	26.6	3.8	1.3	15.5	10.3
Contrast 0 vs Others	***	***	**	***	***
lb P_2O_5/acre	***	***	***	***	***
19	27.7	4.2	1.3	17.3	11.4
37	31.2	4.7	1.5	18.0	14.1
75	38.0	6.1	2.0	24.2	17.7
150	49.5	10.1	3.7	38.2	30.3
300	63.0	13.4	5.4	50.3	41.8
LSD (0.05)	7.6	2.0	0.9	7.4	6.6
Placement	***	***	***	***	***
Band	47.8	9.6	3.7	37.1	29.1
Broadcast	35.9	5.8	1.9	22.1	17.0
LSD (0.05)	4.8	1.3	0.6	4.7	4.1
Rate X Placement	***	***	***	***	***

[1]Soil samples taken in the row at the 0-6 inch depth.

, * Significant differences between treatments at the *P*=0.01 or 0.001 level, respectively.

Table 10. Soil-extractable P in the P7 test in 2007.[1]

	Acetic	Mod Acetic	Water	Bray 2	Mehlich 3
	--------------------------mg P/dm^3-------------------				
No P	26.6	3.6	1.5	14.2	12.7
Contrast 0 vs Others	***	**	**	***	***
lb P_2O_5/acre	***	***	***	***	***
19	30.2	4.1	1.7	17.4	15.4
37	32.6	5.3	2.0	19.5	17.0
75	38.5	6.9	2.5	26.9	24.3
150	63.2	12.1	4.6	48.4	41.8
300	96.6	24.6	9.6	87.9	81.4
LSD (0.05)	14.4	4.1	1.5	11.9	12.9
Placement	***	***	***	***	***
Band	65.9	14.3	5.7	53.6	48.1
Broadcast	38.5	6.9	2.4	26.4	23.8
LSD (0.05)	9.1	2.6	0.9	7.5	8.1
Rate X Placement	***	***	***	***	***

[1]Soil samples taken in the row at the 0-6 inch depth.
, * Significant differences between treatments at the *P*=0.01 or 0.001 level, respectively.

Table 11. Soil-extractable P in the P8 test in 2006.[1]

	Acetic	Mod Acetic	Water	Bray 2	Mehlich 3
	--------------------------mg P/dm^3-------------------				
No P	25.3	4.2	1.7	23.7	19.2
Contrast 0 vs Others	†	*	***	*	*
lb P_2O_5/acre	*	***	***	**	**
19	37.8	6.6	3.1	34.5	31.1
37	41.0	7.2	3.6	39.8	34.0
75	75.8	8.5	4.2	62.8	60.5
150	50.1	9.3	4.8	48.4	42.1
300	86.0	17.2	8.4	87.4	74.8
LSD (0.05)	36.9	4.6	1.6	25.6	26.2
Placement	NS	**	***	*	NS
Band	64.4	11.8	5.9	64.0	55.0
Broadcast	51.9	7.8	3.7	45.1	42.0
LSD (0.05)	23.3	2.9	1.0	16.2	16.6
Rate X Placement	†	**	***	**	*

[1]Soil samples taken in the row at the 0-6 inch depth.
NS, No significant difference between treatments.
†, *, **, *** Significant differences between treatments at the *P*=0.10, 0.05, 0.01 or 0.001 level, respectively.

Table 12. Soil-extractable P in the P9 test in 2008.[1]

	Acetic	Mod Acetic	Water	Bray 2	Mehlich 3
		--------------------------mg P/dm^3-------------------			
lb P_2O_5/acre					
0	87.7	21.6	2.6	20.3	11.5
19	94.0	22.9	2.7	22.2	10.5
37	92.3	24.3	3.1	22.7	10.0
75	100.1	23.6	3.6	26.1	12.5
150	116.7	32.1	6.6	41.5	25.6
300	168.4	54.7	16.7	71.7	56.2
F-test	***	***	***	***	***
LSD (0.05)	20.9	6.6	2.8	9.4	9.8

[1]Soil samples taken in the row at the 0-6 inch depth.
*** Significant differences between treatments at the *P*=0.001 level, respectively.

Table 13. Soil-extractable P in the P9 test in 2009.[1]

	Acetic	Mod Acetic	Water	Bray 2	Mehlich 3
		--------------------------mg P/dm^3-------------------			
lb P_2O_5/acre					
0	73.3	22.0	2.8	22.7	9.1
19	80.6	23.2	3.1	23.6	9.6
37	94.6	25.3	4.1	25.5	10.6
75	92.8	27.7	4.8	33.1	16.1
150	112.7	36.2	8.0	47.6	29.0
300	183.0	66.6	19.3	107.6	82.7
F-test	***	***	***	***	***
LSD (0.05)	17.0	4.6	1.8	10.6	9.1

[1]Soil samples taken in the row at the 0-6 inch depth.

*** Significant differences between treatments at the *P*=0.001 level, respectively.

Table 14. Soil-extractable P in the P10 test in 2008.[1]

	Acetic	Mod Acetic	Water	Bray 2	Mehlich 3
		--------------------------mg P/dm^3-------------------			
lb P_2O_5/acre					
0	605.1	313.3	35.4	395.5	344.6
19	530.0	276.3	30.8	349.0	306.2
37	496.0	251.0	31.2	327.8	287.5
75	535.1	265.4	33.4	338.9	295.5
150	640.0	277.7	36.2	374.7	324.9
300	604.3	320.7	47.2	424.6	486.3
F-test	NS	NS	**	NS	NS
LSD (0.05)	186.3	91.6	7.5	109.9	236.8

[1]Soil samples taken in the row at the 0-6 inch depth.

NS, No significant differences between treatments.

** Significant differences between treatments at the *P*=0.01 level, respectively.

Table 15. Leaf P concentrations in the P7 test in 2005, 2006, and 2007.

	2005	2006	2007
	-------------------% P---------------		
No P	0.226	0.184	0.182
Contrast 0 vs Others	***	***	***
lb P_2O_5/acre	***	**	***
19	0.237	0.194	0.196
37	0.242	0.194	0.214
75	0.237	0.199	0.222
150	0.253	0.202	0.223
300	0.249	0.205	0.231
LSD (0.05)	0.008	0.007	0.007
Placement	NS	NS	**
Band	0.245	0.199	0.220
Broadcast	0.242	0.199	0.214
LSD (0.05)	0.005	0.004	0.004
Rate X Placement	†	NS	NS

NS, No significant differences between treatments.
†, **, *** Significant differences between treatments at *P*=0.10, 0.01, and 0.001, respectively.

Table 16. Leaf P concentrations in the P8 test in 2005.

	% P
No P	0.226
Contrast 0 vs Others	NS
lb P_2O_5/acre	NS
19	0.223
37	0.233
75	0.229
150	0.230
300	0.230
LSD (0.05)	0.008
Placement	NS
Band	0.228
Broadcast	0.230
LSD (0.05)	0.005
Rate X Placement	†

NS, No significant differences between treatments.
† Significant differences between treatments at *P*=0.10.

Table 17. Leaf P concentrations in the P9 test in 2007 and 2008.

	2007	2008
	-------------% P------------	
lb P_2O_5/acre		
0	0.173	0.120
19	0.204	0.173
37	0.221	0.182
75	0.221	0.202
150	0.224	0.219
300	0.233	0.233
F-test	***	***
LSD (0.05)	0.024	0.012

*** Significant differences between treatments at *P*=0.001.

Table 18. Leaf P concentrations in the P10 test in 2007.

lb P_2O_5/acre	% P
0	0.255
19	0.258
37	0.253
75	0.260
150	0.255
300	0.263
F-test	NS
LSD (0.05)	0.013

NS, No significant differences between treatments.

Table 19. Initial soil test values in previous phosphorus fertilizer rate tests.

Location	pH	Acetic	Mod Acetic	Water	Bray2	Mehlich3
		------------------------mg P/dm^3--------------------				
P4	7.3	49.4	19.9	5.7	NA	28.7
P5	7.0	91.3	19.8	2.7	NA	14.6
P6	6.9	44.2	11.3	3.9	NA	10.1
USSC1	6.6	15.4	NA	1.8	6.3	6.5
USSC2	4.8	15.0	NA	9.8	6.8	7.4

NA, Not available.

Extractable mg P/dm^3 is equivalent to mg P/L soil.

Table 20. Relative tons sugar/acre values for available phosphorus rate tests.

Site	Crop	Control Plot Relative Tons Sugar/Acre[1]
P4	P	0.91
	S1	0.96
	S2	0.98
P5	P	1.00
	S1	1.00
	S2	0.94
	S3	0.86
P6	P	1.00
	S1	0.98
	S2	0.96
P7	P	0.92
	S1	0.90
	S2	0.86
P8	P	1.00
P9	S1	0.70
	S2	0.39
USSC1	P	0.84
	S1	0.79
	S2	0.71
	S3	0.67
USSC2	P	0.77
	S1	0.83
	S2	0.46
	S3	0.56

[1]Relative tons sugar/acre (TSA) determined by dividing control plot mean TSA by the highest treatment mean TSA for each year at each site.

Table 21. Proposed sugarcane phosphorus fertilizer calibration for Florida organic soils. All fertilizer rates are for banded application.

Mehlich 3 Soil P	**Fertilizer P Rate**
mg/dm^3	lb P_2O_5/acre
Plant	
≤ 10	75
11-15	60
16-20	50
21-30	40
> 30	0
Ratoon 1 & 2	
≤ 10	75
11-15	60
16-20	50
21-35	40
> 35	0
Ratoon 3+	
≤ 20	50
21-40	40
> 40	0

Table 22. Change in Mehlich 3-extractable soil P over time in control plots of previous phosphorus rate tests.[1]

	Phosphorus Rate Test		
Year	P4	P5	P6
	-------Mehlich 3 P (mg/dm^3)-------		
Initial Sample	28.7	14.6	10.1
1	34.9	22.9	23.1
2	17.1	14.4	9.0
3	12.7	13.3	5.7
4	NA	8.6	5.2

NA, Not available.

[1]Initial sample was taken in fall when each test was established. Other samples were taken during the March-June period each year.

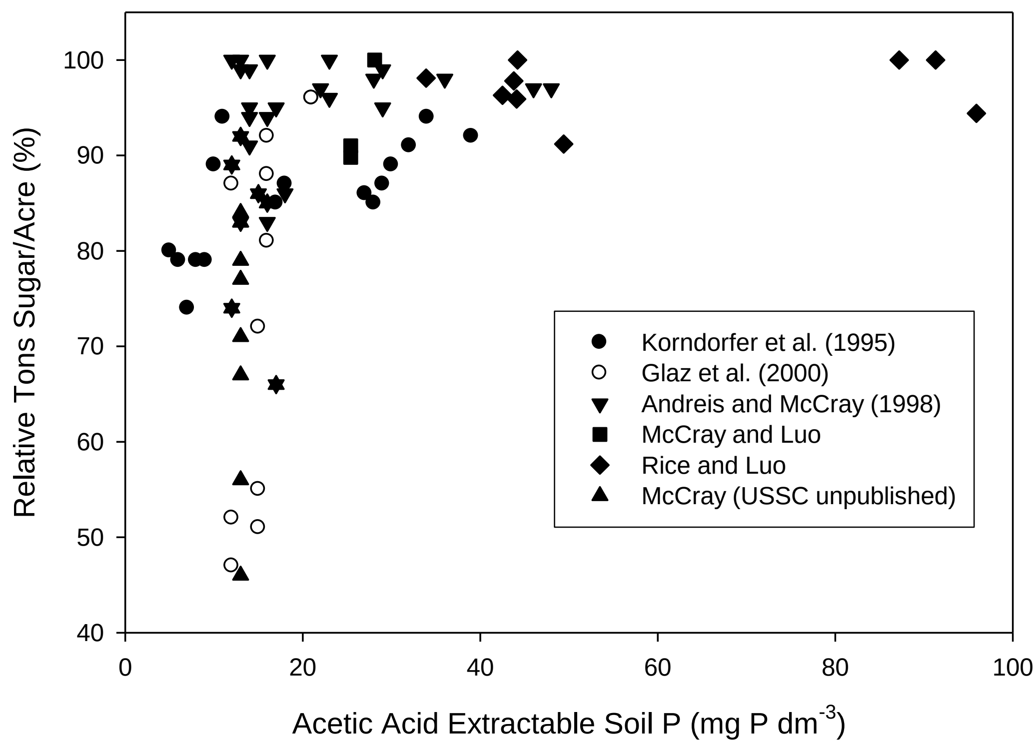

Figure 1. Relationship between relative sugar yield and initial acetic acid-extractable soil phosphorus in studies conducted on organic soils in Florida. Source of research is noted in index of figure.

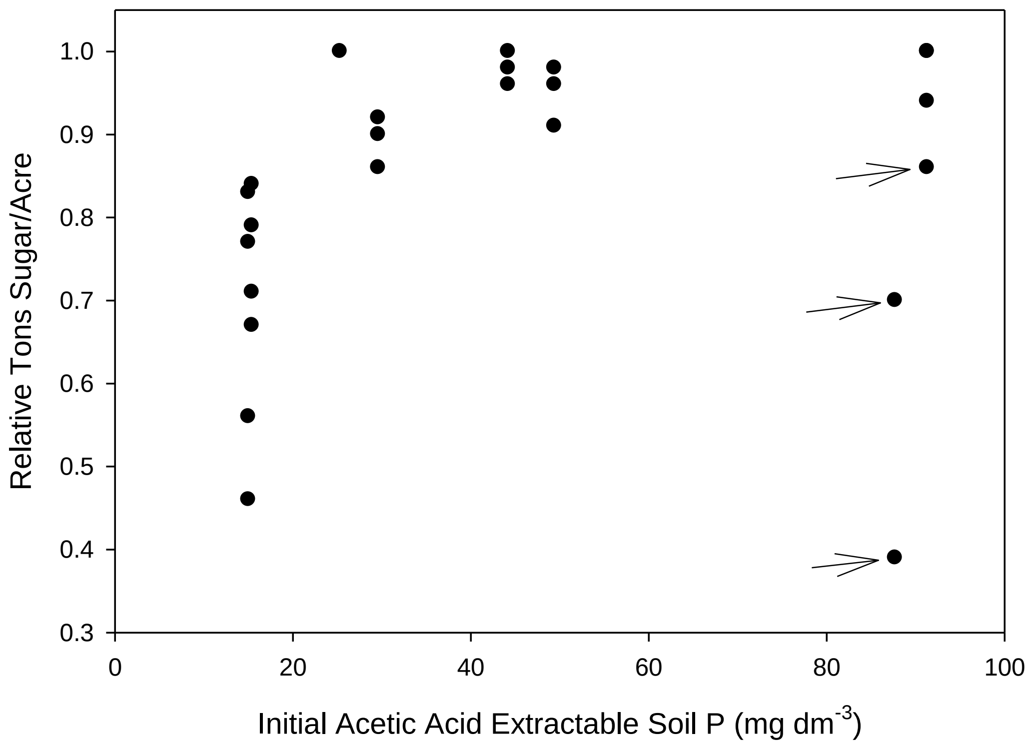

Figure 2. Relationship between relative sugar yield and initial acetic acid-extractable soil phosphorus in recent studies by J. M. McCray, R. W. Rice, and Y. Luo at UF/IFAS and U. S. Sugar Corporation. Points noted by arrows are from the P5 and P9 tests.

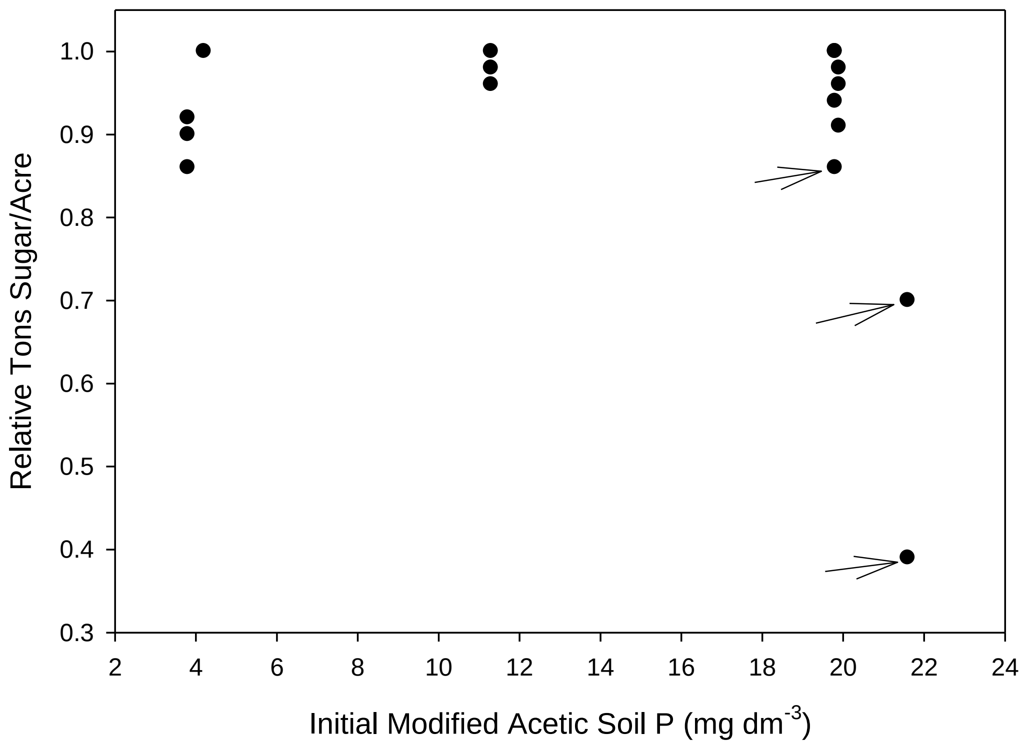

Figure 3. Relationship between relative sugar yield and initial modified acetic acid-extractable soil phosphorus in recent studies by J. M. McCray, R. W. Rice, and Y. Luo at UF/IFAS and U. S. Sugar Corporation. Points noted by arrows are from the P5 and P9 tests.

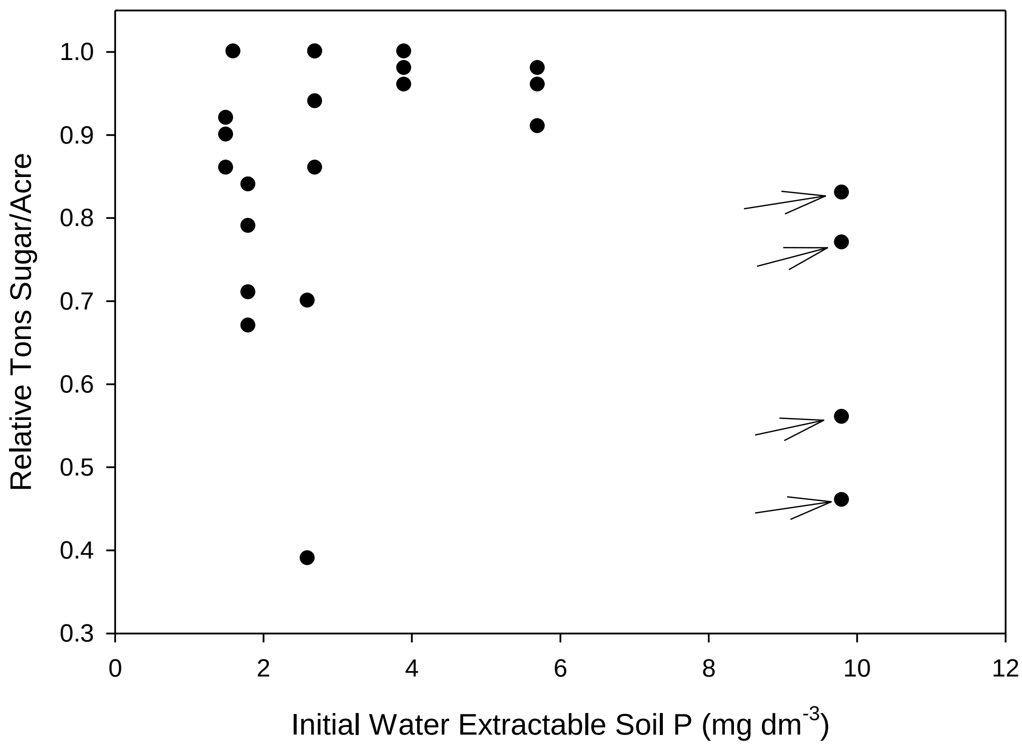

Figure 4. Relationship between relative sugar yield and initial water-extractable soil phosphorus in recent studies by J. M. McCray, R. W. Rice, and Y. Luo at UF/IFAS and U. S. Sugar Corporation. Points noted by arrows are from a previous test at U. S. Sugar.

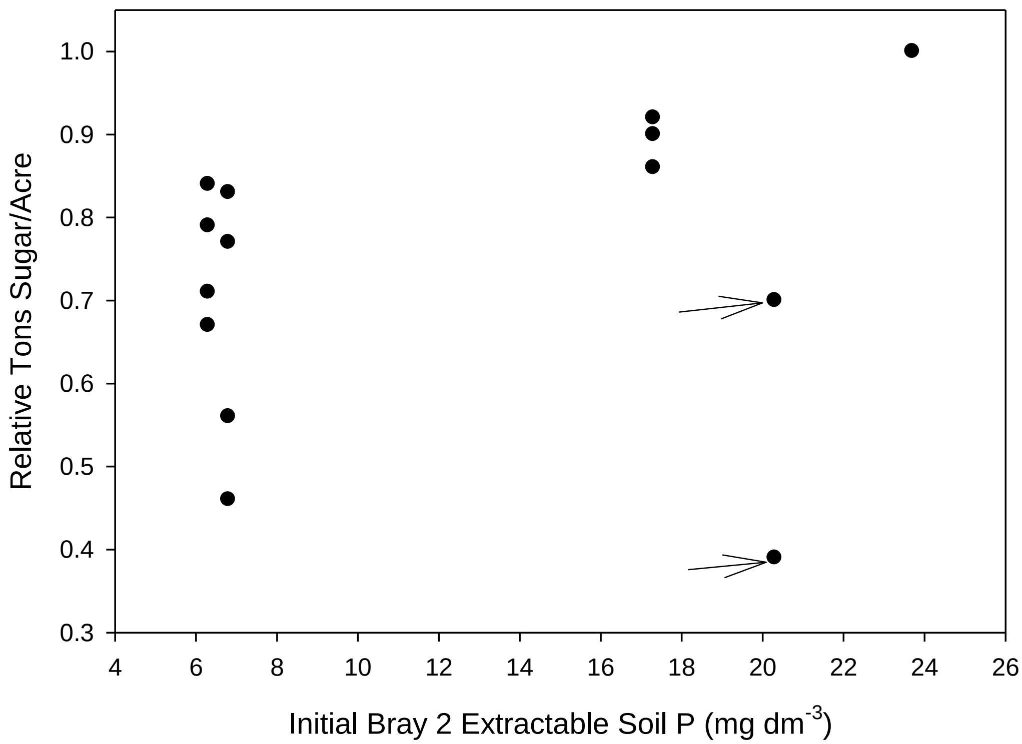

Figure 5. Relationship between relative sugar yield and initial Bray 2-extractable soil phosphorus in recent studies by J. M. McCray, R. W. Rice, and Y. Luo at UF/IFAS and U. S. Sugar Corporation. Points noted by arrows are from the P9 test.

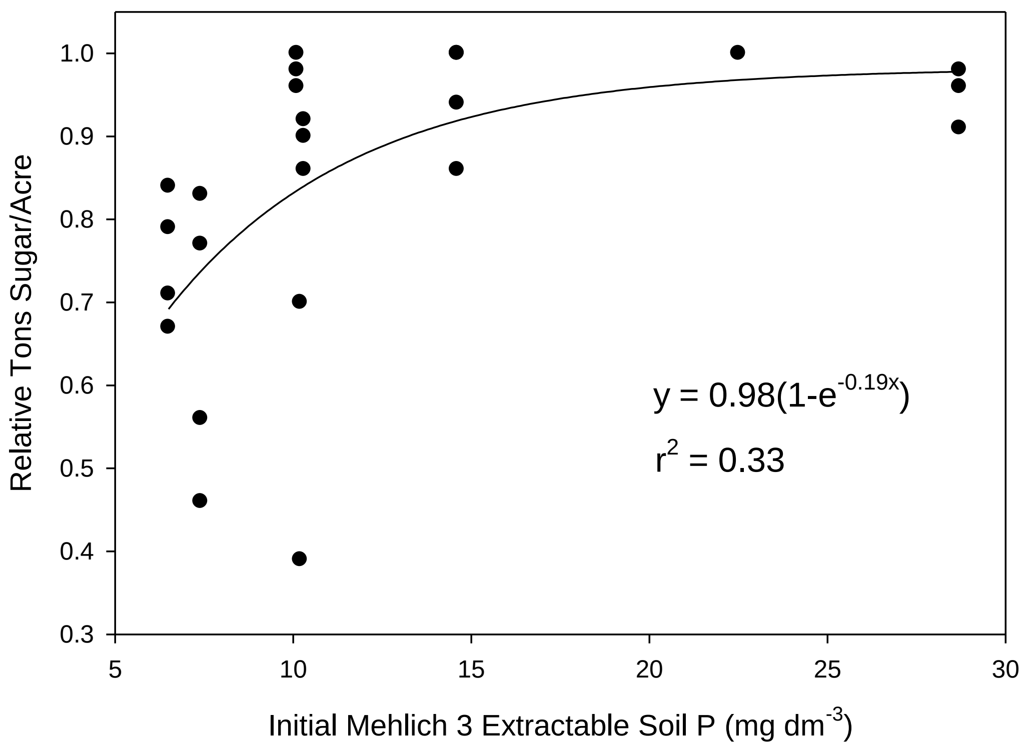

Figure 6. Relationship between relative sugar yield and initial Mehlich 3-extractable soil phosphorus in recent studies by J. M. McCray, R. W. Rice, and Y. Luo at UF/IFAS and U. S. Sugar Corporation.

Appendix A

Current IFAS Sugarcane Phosphorus Fertilizer Recommendations

Everglades Soil Testing Laboratory

Sugarcane Fertilization Recommendations

Everglades Research and Education Center
University of Florida / IFAS
3200 East Palm Beach Road
Belle Glade, FL 33430

	Phosphorus Fertilization Recommendations											
Sugarcane crop	Soil-test index $\mathbf{P_w}$ levels (water extractable phosphorus)											
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**> 10**
	Recommended lbs P_2O_5/acre											
Plant cane	75	75	70	60	60	40	40	0	0	0	0	0
1st ratoon	75	75	70	60	40	40	40	40	40	0	0	0
2nd ratoon	70	50	40	40	40	40	40	40	40	40	40	0
3rd + ratoon	40	40	40	40	40	40	40	40	40	40	40	40